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SEWERAGE AND SEWAGE DISPOSAL OF A SMALL TOWN.

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OF A

SMALL TOWN.

BY

E. B. SAVAGE, A.M.Inst.C.E.

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PREFACE.

The following pages are a reprint of a series of articles which originally appeared in the *Contract Journal*. The author has endeavoured more to indicate to young engineers the applications of well-known principles rather than to dwell upon these principles. He has, in the course of his experience, found men well equipped with what may be termed the tools of their profession, but lacking ability to use those tools. It has been his endeavour to show them how to use the tools already to their hands, and trusts that his efforts in this direction may be found useful.

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CHAPTER I.

INTRODUCTORY.

The important position which sanitary engineering has of late years assumed in the work of most civil engineers, whether practising privately or holding public appointments as surveyors or sanitary inspectors, renders any discussion as to the means adopted for dealing with the liquid refuse of towns of more than usual interest. Owing to the fact that such excellent works as those written by Mr. Bailey Denton, Mr. Baldwin Latham, and Mr. Santo Crimp are already well known to all those who take an interest in the question of sanitation, it is not proposed in the following pages to enter upon the principles which form the basis of sanitary engineering, but rather to describe in as simple a manner as possible a practical application of the principles advocated. To do this it is intended to take the case of a small town, such as an engineer may most likely be called upon to deal with in ordinary practice; to describe, one by one, the various steps necessary to take, in order to enable him to design an efficient scheme of sewerage, and to illustrate and apply one of the systems of sewerage purification which may appear suitable in the special case under notice.

As necessarily, in dealing with such a popular subject, much may be brought forward which to engineers of long experience may hardly seem worthy of notice; still, it is to be hoped that a few of the hints and practical details to be given hereafter may be of assistance to the younger body of professional men, and to those who perhaps for the first time in their career are called upon to design a scheme of sewerage and sewage disposal, and who, though conversant with the details of sewer construction, may not have had the opportunity of assisting in the actual conception and designing of an entire scheme.

Before entering upon the main subject, it may not be out of place to go back a few years, and make a brief review of the methods of sewering as practised up to a comparatively recent date; and, further, for the sake of comparison, to refer to some of the improvements adopted in modern practice, and which, in their turn, may indicate the direction in which further improvements may be looked for.

CHAPTER II.

OLD SEWERS.

The most ordinary form adopted in the construction of sewers up to within 30 or 40 years was a simple square or rectangle, of which the height was usually somewhat greater than the breadth, the invert consisting of bricks set on edge, either perfectly flat or slightly inverted ; only where sanitary matters were better understood and looked after do we find the circular form adopted. In localities where stone could be obtained cheaply, we find it much used in sewer work—the invert being formed of rough rubble set on edge, or sometimes a single flag carried right across and supporting the rubble sides over which a flag was laid to form the top.

The masonry as well as the brickwork in old sewers will be frequently found laid dry without any cementing material or mortar, it being supposed that the sewage in percolating through the joints filled them up, rendering them as watertight as necessary.

Anything more opposed to our modern ideas of sanitation can hardly be imagined ; in the case where rubble was used, each hollow or projection would tend to retard the flow of the sewage, the sewer in a short time becoming choked up with filth, which would have to be removed periodically at great expense. Further, owing to the open joints, the ground for a considerable distance around the sewer would become thoroughly saturated with sewage; and when it is remembered that it was no unfrequent thing to construct sewers under inhabited dwellings, the danger to the health of the inmates can hardly be estimated.

Another cause of the silting up of old sewers was the little care taken in designing the gradients, and the still more careless manner in which they were set out. On one portion of a sewer we find perhaps scarcely any fall, the next length falling more rapidly than necessary, and where by the exercise of a little judgment, and a slight extra expenditure in excavation, the sewer could have been constructed throughout its entire length with sufficient fall to prevent the deposit of solid matter.

The usual means of access to these sewers consisted of badly-constructed square shafts, which in the case of small sewers were generally so far apart that it was impossible to reach any obstruction by means of the ordinary tools used by sewermen. In such cases the street would have to be opened up, the sewer broken into, and subsequently made good.

Where such shafts existed at fairly short intervals of, say, 200 or 300 yards, a slight circulation in the air of the sewer would take place, but where the distances apart were greater the effect would be hardly appreciable, the air rising from such manholes being foul and offensive in the extreme. Unfortunately, the means adopted to remedy the nuisance was in reality only an aggravation of the evil, the shaft being either hermetically built up or a full iron cover placed where a perforated one had previously existed. The connection with the open air being still further cut off, the sewer air would become highly concentrated and dangerous, easily finding its way into dwellings through the least defect in internal fittings.

As regards the means adopted for getting rid of the sewage, the usual method was to run the sewer to the nearest river or watercourse, there to discharge its foul contents to undergo further putrefaction perhaps miles away down stream. In consequence of this obnoxious practice the rivers of England some 35 years ago were in such a bad state that Royal Commissions were appointed to examine and report. In one of these reports we find the following statement: "That the increasing pollution of the rivers and streams of this country is an evil of national importance which urgently demands the application of remedial measures; that the discharge of sewage and noxious refuse of factories into rivers is a source of nuisance and a danger to health. . . . ."

The result of the various reports of these and other commissions led the Legislature to frame and pass the Public Health Act, 1875, which, besides consolidating previous Acts, laid down more stringent regulations as to the means to be taken in getting rid of sewage. This important Act, together with the Rivers Pollution Act, 1876, should be carefully studied previous to attempting to carry out a sewerage scheme, as by these, powers and facilities are conferred and restrictions placed on local authorities which did not exist previously.

The oldest and to this day the most satisfactory method of dealing with sewage so as to render it harmless, is by means of irrigation over cultivated land: in some cases it was simply conveyed in its crude state on to the land; in others the solids were removed by precipitation in tanks previous to its application on the land.

The towns of Edinburgh and Rugby tried at one time the idea of conveying the liquid under pressure through underground pipes, from which it was applied to the land by means of a hose and jet. Such a complicated system, needless to say, did not prove a success owing to the excessive cost of construction and the subsequent maintenance.

The use of lime as a precipitant and deodorant, though well known at an early date in connection with sewage treatment, does not seem to have been much used until later, when local authorities were compelled to obtain a higher state of purity in their effluent sewage. Other chemicals and substances were also tried with varying success, but to these we will have occasion to refer in a subsequent chapter.

CHAPTER III.

IMPROVEMENTS IN SEWER CONSTRUCTION.

Having described one of the old forms of sewers, and the method of sewering as practised a few years ago, we will now touch on a few of the most important improvements that have been effected since the period referred to.

Form of Sewers.—After trying various forms, engineers are now agreed that, under ordinary circumstances, the circular and that known as the egg-shaped sewer give the best results. Where a considerable volume of sewage has to be conveyed, as in the case of an intercepting or outfall sewer of a large town, the circular form possesses many advantages, being strong and easy to construct, besides having the largest carrying capacity in proportion to the material required for its construction. But as the flow in ordinary sewers is liable to great fluctuations, according to the hour of the day, or through a sudden influx of storm water as experienced particularly in hilly districts, or in manufacturing towns through the intermittent discharge of large quantities of refuse water from bleaching, dye, and other works, the egg-shaped sewer should, if possible, be used, since with a minimum flow a sewer so formed presents considerably less surface to the fluid, consequently less resistance is set up than in a circular sewer of equal area delivering the same quantity. Circumstances will, however, frequently arise in practice which render it necessary to deviate from any fixed rule; thus a storm-water sewer may very properly be constructed circular instead of egg-shaped, since during the time it is in operation the sewage is very largely diluted, and it is necessary at such times to have a sewer of the largest carrying capacity to carry away the storm water in the shortest time. It will also be found necessary at times to adopt a special form of sewer, as, for instance, where it has to be carried under obstacles such as large gas or water mains, bridges, etc., the removal of which could only be effected at great cost and inconvenience.

Materials.—Large sewers are constructed either in brickwork or Portland cement concrete, and occasionally a combination of the two. In making his selection of these two materials, the engineer will have to be guided by local circumstances as to which to adopt.

Brick Sewers.—If bricks of a suitable quality can be obtained, they make a very good sewer; but it will be necessary, in order to reduce the width of the joints at the back of each ring of brickwork, to use a certain number of specially radiated bricks in conjunction with the square ones.

The invert, being subject to greater wear than the sides and arch through the grinding action of the sand and solid particles washed into the sewers from the streets, should be formed of the best and hardest brick obtainable. Blue Staffordshire bricks are now much used for this purpose, being extremely hard, and not affected to any extent by the sewage. Many engineers recommend the use of glazed stoneware invert blocks, but in the form in which they are usually made they have the disadvantage of being weakest at the centre, where the strain from the weight of the superincumbent brickwork is greatest. Therefore, unless laid on a very solid foundation or well backed with concrete, they are liable to fracture. In localities where subsoil water has to be dealt with, and where otherwise a separate subsoil drain would have to be constructed, a special form of stoneware invert block is sometimes used, the lower part when laid forming a continuous channel, into which the water passes, and is conveyed away without endangering the foundation of the main sewer.

All brickwork in sewers should be set in either Portland cement or lias lime mortar. In wet ground the former should be used, and even in ordinary circumstances, with the low price at which cement can now be obtained, and the many advantages it possesses, the use of lime may be considered a doubtful economy.

Concrete Sewers.—Concrete made of good Portland cement and hard stone is an excellent material for sewers. Forming when completed a homogeneous mass, without any joints to allow of the escape of the sewage, its employment also enables sewers to be made in special forms, and in positions in which other materials could hardly be used. The use of concrete, more particularly perhaps in sewer work than any other, necessitates very careful supervision owing to the facilities afforded to put in bad work and economise cement.

Pipe Sewers.—For smaller sewers, from 18in. diameter downwards, glazed stoneware pipes with sockets are universally used, and if of the proper thickness are strong enough to withstand the heaviest traffic, and being coated both inside and outside with a hard glaze, are impervious, easy to clean, and not injuriously affected by the sewage. Pipes of good quality when fractured should present an almost metallic appearance, and should be capable of withstanding a test head of 40ft. or 50ft. of water without showing signs of sweating.

Opinions greatly differ as to the largest size of pipe safe to adopt in practice. Many engineers use them up to 24in. diameter, and even larger; but although such pipes may stand where the traffic is light, or through open fields, it is open to doubt whether they may safely be laid in the streets of large towns, exposed as they are to the disturbance and vibration caused by traction engines and steam-rollers. In such cases it is decidedly safer to construct sewers of 24in. and upwards in brickwork or concrete.

Pipe Joints.—Notwithstanding that so much depends on the manner in which pipes are jointed, it is surprising to see such widely different views existing on this point amongst engineers.

Many still specify the joints to be filled with puddled clay, whilst others, in addition, encase the whole socket in a mass of the same material, which certainly tends to make a more watertight joint. Clay, although very suitable for temporary work, owing to the ease with which pipes can be taken out and relaid, is for many reasons strongly condemned by some of the best authorities on sewer work, the principal objections being its solubility when exposed to running water, and the liability of its being forced out of the joint when the weight of the material above comes to press on the pipes.

Cement or cement mortar makes a good joint not liable to the above-mentioned objections; but in order to prevent the cement from being forced into the pipes, the joints should be caulked first with two or three strands of tarred gaskin, which also permits of the pipes being adjusted in their proper position concentrically, and so retained until the cement has had time to set. Another advantage from the use of gaskin is that should any water find its way into the newly-laid pipes, which frequently happens, it will be prevented from coming into direct contact with the cement, consequently little harm is likely to arise. Besides the above-mentioned there are several patent joints; in some of these a special jointing material is used, whilst in others it is entirely dispensed with, the spigot end being simply forced into the socket after the manner of a turned and bored water or gas pipe. Such pipes, although considerably more expensive than the ordinary ones, may with advantage be used in special cases, as in wet or marshy land. The best known of these patent joints are Hassall's, Stanford's, Doulton's, and Sykes', these latter being screwed together in jointing.

Inspection.—Notwithstanding every precaution made to prevent it, stoppages will occur in sewers; it is therefore obligatory in every scheme to provide an efficient means for locating the obstruction, and then removing it. In brick sewers large enough to admit a man, this can be effected without much difficulty; but in pipe sewers, which are more liable to stoppage, special provision will have to be made in the shape of inspection chambers, or manholes, placed sufficiently near that any intermediate point may be reached by the cleaning tools ordinarily used for the purpose. The limit of length in which such rods can be conveniently manipulated being from 70 to 80 yards, twice this distance may be taken as the maximum distance between any two manholes.

Lampholes.—At a point, if possible, midway between the manholes where their distance apart exceeds 70 or 80 yards, a pipe shaft should be carried up to the surface of the roadway, terminating with a movable cover, through which a lamp on being lowered into the sewer will be visible from the manholes on either side, provided no obstruction exists at an intermediate point. This method of inspection gives us an important reason why all pipe sewers should be constructed in straight lines between each opening, and the necessity for placing a manhole or lamphole at every change of direction and inclination, and a manhole at every junction of branch sewers. Another advantage will also show itself when the exact position and depth of the sewer is required at an intermediate point for the purpose of making a branch connection — the first being easy to ascertain on the ground, the second by calculation, the distance from the nearest manhole or lamphole being known, together with the inclination from this point.

Ventilation.—Sir Robert Rawlinson in his valuable "Suggestions on Sewerage, etc., Works," recommends openings from the sewer to the street at a maximum distance of 100 yards apart. This will be obtained by providing both manholes and lampholes with perforated covers, means, however, being taken to prevent sticks and road sweepings from falling into the sewer. Various other methods of ventilation have been tried, such as hollow shafts of sheet metal, placed at the side of the road and carried up to a considerable height, utilising lamp-posts, factory chimneys, etc.; but although some of these latter methods may be used under special circumstances—as, for instance, where, owing to the extreme narrowness of the street, open ventilation would be liable to create a nuisance to the passers-by—still, bearing in mind the excessive cost of such special means of ventilation, their universal adoption is not to be recommended in most cases.

Leaving further details of sewer construction to be discussed as the occasion for their practical application arises, we will now revert to the subject before us, and proceed to deal with such points as are likely to present themselves in the designing of a scheme of sewerage for a small town.

General Plan *(No. 1 Sheet of Drawings)*.—In sewerage, as in other works, the first important consideration is to obtain a plan on which to clearly indicate the proposed positions of the sewers, manholes, and other incidental works. To obtain such without going to the trouble and expense of an actual survey, it should be ascertained what plans of the town and district are already in existence; those most suitable for the purpose being the Ordnance maps to the $\frac{1}{2500}$ scale, the 5ft. to the mile, or the $\frac{1}{500}$, which may be reduced as required so as to form a plan of convenient dimensions, and from which the sections may be ultimately plotted. Failing either of the above, enquiries may be made respecting the two chains to the inch parish tithes map, which exists in many parts of England, and sometimes includes the sites of small towns and villages. Since several years have elapsed since the surveys were made, both this and the Ordnance maps may require to be carefully revised on the ground, and any new buildings, roads, etc., shown on in their correct positions. As a last resource, an enlargement may be made of the 6in. Ordnance map, a process which, although somewhat tedious and necessitating great accuracy, is decidedly to be recommended in preference to the attempt frequently made to show a scheme to such a small scale as the last-named Ordnance.

Surface Gradients.—To become thoroughly acquainted with the general surface gradients is the next object to be attained, and one in which the 6in. Ordnance will prove of the greatest assistance ; a careful study of the contours (shown in finely-dotted lines corresponding in their positions to lines of equal altitude on the ground) enabling the undulations of the surface to be traced out with a considerable degree of accuracy. To complete the knowledge thus gained, a thorough and systematic inspection of the district should now be undertaken with a view to ascertaining the main irregularities of the surface, the courses of streams, outlets of existing sewers, and any other matters to be taken account of in designing the scheme. The importance of performing this part of the work leisurely and in a careful manner should in nowise be overlooked, since it is possible that by the oversight of a single point the whole scheme may be prejudicially affected, and have to undergo serious modification when the work comes to be carried out. Moreover, it will frequently happen that the best and most practical ideas suggest themselves whilst on the ground, or when a thorough acquaintance with the district has been acquired.

Contour Plan (*No. 2 Sheet of Drawings*).—For purposes of future reference, and to illustrate graphically the undulations of the surface as they are supposed to exist, we give a reproduction of the "general plan," omitting for the sake of clearness all buildings, and showing the whole town and district for some considerable distance round carefully contoured at every 2ft. in height, the elevation of the contours above Ordnance datum being denoted by figures in the margin. Referring now to the two plans before us, it will be seen that the town we have chosen is intersected by a river, the connection between the north and the south sides being by means of a bridge of the old arched form. On the north side, westward of Padley-road, the contours show the surface to rise with a steady gradient in a northerly direction, whilst eastward, roads are indicated along the summit of a ridge or elevation which is supposed to terminate precipitously at the river in the form of a rocky cliff. On the south side in the central portion of the town the surface is undulating, but ascends gradually as we proceed in a southerly direction, whilst eastward it conforms to a great extent to the general valley line parallel with the river.

Interception.—It will at once be apparent that there are two methods of dealing with the sewers from each portion of the town: firstly, by keeping them entirely distinct, those on the north side being intercepted by an outfall sewer carried for some distance along the north bank of the river, and conveying the sewage to a spot where it can be treated; those on the south side being similarly intercepted by sewers along the main roads leading also to a convenient place for treatment. The second scheme is obviously to connect both systems of sewers at a suitable point, either by means of the bridge already existing, or by an iron pipe laid under or over the river, the united volume of sewage being then conveyed to a site where after purification it may be discharged into the nearest natural watercourse. Comparing the advantages and disadvantages of each scheme, in the first we have an additional outfall sewer which would greatly increase the first cost, more particularly as it would have to be constructed for its entire length through private land, for which compensation would be demanded, and which even then during the growing of the crops would only be accessible with difficulty; again, the erection and maintenance of two separate works is of itself sufficient reason why it should be condemned. In the second scheme none of the above objections occur, the sewers could be constructed almost entirely along the main roads, and the sewage conveyed to one site where it could all be treated together. With the many advantages it possesses we need therefore have no hesitation in adopting the last-mentioned scheme, and can now proceed to consider the first question which arises—viz., the selection of a suitable site for the works.

CHAPTER IV.

POSITION OF WORKS.

Site of Works.—The most favourable position for a site on which to erect the works will be that to which the whole volume of sewage may be conveyed either by gravitation, or where, if pumping has to be resorted to, use may be made of any natural watercourse of sufficient volume and fall to furnish the necessary power without the aid of steam. The least favourable site will be that in which the entire sewage has to be raised by steam power before it can be passed on to the land. To ascertain now whether we can adopt a gravitation scheme, accurate levels should be taken, not only of the lowest roads where buildings exist, but of any land likely to be laid out at a future time for building purposes. Referring to the "contour plan" as a substitute for actual levels, we find the lowest land on the north side to be near the bridge, the contours there indicating it to be 133ft. above Ordnance datum, whilst on the south side, the lowest portion is that at the junction of Tolwich-road and Market-street, the surface there being 132ft. above Ordnance datum, which point, therefore, will practically govern the level at the outfall, enabling it to be fixed in the manner we are about to describe, and to give an idea as to the practicability or otherwise of a gravitation scheme. From experiments carried out it has been ascertained that to prevent ordinary town sewage, in combination with a certain amount of surface water from street surfaces, from depositing the solid matters which are continually carried along in suspension, a velocity of at least 2·5ft. per second has to be given to the flow. This is obtained by laying the sewers at given inclinations, varying according to the size of the sewer and the volume of sewage to be conveyed; such inclinations may either be got from printed tables of velocity or by making use of the following formula, which has the advantage of being short and easy to apply:

$$H = \frac{7 \cdot 56}{2r},$$

in which H = fall in feet per mile, and

r = hydraulic radius, or the sectional area of the fluid divided by the length of the wetted border, both being expressed in feet.

To make use of this formula, we shall assume the sewer from the lowest point in Tolwich-road to the outlet end beyond the town to be an 18in. pipe running full or half-full, and find as the result that a fall of 10ft. per mile, or 1 in 528, is necessary in order to obtain a velocity of 2·5ft. per second. In addition to this inclination, a further fall will have to be provided at the outfall to enable the sewage to gravitate through the works, this amount varying according to the treatment adopted; or to put it more correctly, the works being so designed as to utilise whatever fall is available, which in some cases may be only a few inches, whilst in more favourable situations as many feet may be obtained and turned to good account.

Irrigation Area.—Owing to the fact that at the present time no entirely satisfactory process has been discovered by which sewage can be thoroughly purified, either mechanically or by the use of such chemicals as are not rendered prohibitive by their cost, and that the clearest of effluents, unless passed through artificial filters, or on to the surface of land properly prepared, is liable to undergo a secondary putrefaction some time after its admittance into a river, being the frequent cause of pollution at a considerable distance from the point where it was discharged, it has come to be regarded as an almost essential feature in every sewerage scheme, that an area of land more or less extensive be provided on which to discharge the sewage previous to its admittance into any natural stream. Guided by the above considerations, we are now in a position to determine at what level land would have to be situated to enable the sewage to be delivered on to the surface by gravitation simply, and without, if possible, flattening the gradient, which would necessitate the provision of special flushing arrangements. As already stated, the lowest surface level in the town was found to be 132ft. By placing the sewer at this point 8ft. deep, we get 124ft. as the invert level: therefore if the sewer discharge at a site half a mile distant, 119ft. would be the level when the sewage enters the works; by allowing a fall of, say, 3ft. in its passage through the works, 116ft. above Ordnance datum will be the level of the sewage as it issues from the works, therefore only land situated below this level will be available for the purpose of an irrigation area. To ascertain whether land at the above-stated distance and level does exist will be simply a question of levelling; a careful comparison of the heights obtained at different points enabling it to be easily seen which sites are best suited to the circumstances. In the case before us, with a well-defined valley-line, almost immediately on leaving the town we shall come to an area of considerable extent situated between the main road and the river,* the surface at the upper end adjoining the former being 116ft., from whence it slopes to the river, being there 104ft. above Ordnance datum, or about 6ft. above ordinary water-level, which in times of flood rises 2ft. This site, therefore, in the present state of our knowledge, and so far as the levels are concerned, appears satisfactory, but before committing ourselves to its adoption, it will be advisable to verify the assumptions we have made in regard to the depth and gradient of the main sewer, since we may find these have to undergo modification, either to suit the surface of the ground, or in consequence of the levels of branch sewers which have to be intercepted.

* For the convenience of illustration, the site for the works has been chosen in close proximity to the town; in practice it would be desirable to increase this distance.

CHAPTER V.

ARRANGEMENT OF SEWERS.

Position in Roadway.—Before proceeding to lay out the lines of sewers, together with the necessary number of inspection chambers and ventilating openings, the question will present itself as to what is the correct position for a sewer to occupy with regard to the roadway, in order that it may fulfil most effectually the purpose for which it is intended—viz., the removal of domestic sewage, liquid waste from manufactories inadmissible into natural watercourses, and the foul scourings from the surface of roads, yards, etc., which with moderate rainfall may with advantage be admitted into the sewer, and treated as ordinary sewage. A little consideration of the subject will lead to the conclusion that the centre of the road for several reasons offers the greatest advantages, and where ample width of roadway and other circumstances admit of it, the sewer should be so placed, it being then equidistant from the buildings on either side, thus allowing of the branch drains from these being laid at better inclinations than if the main sewer were placed over to one side of the roadway, it being in this position further removed from the adjoining buildings on one side. Another advantage in favour of adopting the centre line will show itself when the private drains come to be carried out, as the roadway can be opened up from the main sewer to the building line for the full distance without seriously interfering with the traffic—one half of the roadway always remaining undisturbed.

Where, however, the road is on the curve, to keep the sewer strictly to the centre would necessitate the sewer being also curved, which, although frequently done, should in no case be permitted, upsetting as it does the important principle already laid down—viz., that all pipe sewers be laid in straight lines from point to point for the purposes of inspection, bends being only admissible at either inspection chambers or lamp-holes. In such cases, in order to carry the sewer round the curve, it will be necessary to lay the same in a series of chords, placing at each change of direction a manhole or lamphole as may be deemed expedient.

Another reason constantly occurring in the execution of the work, and which necessitates placing the sewer away from the centre line of the roadway, is the existence of gas or water mains. Where this occurs, sufficient space should be left between these and the sewer trench to avoid any disturbance; still, with a properly timbered trench, well rammed during the filling in, little apprehension need be felt provided the ground supporting the pipes is not removed.

Depth of Sewers.—In large towns most authorities agree that 9ft. or 10ft. is a convenient depth for the main sewers, whilst in suburban districts and small towns this depth may be somewhat reduced. In fixing the depth, it will be necessary to take into account back property which may require to be drained, and which, if below the level of the roadway, would necessitate a corresponding increase in the depth of the main sewer. For branch drains a fall of at least 1 in 70 throughout their entire length should be allowed for, in addition to a further drop of a few inches taking place in the junction pipe on the main sewer.

Levels.—To revert again to the main subject, it will now be necessary to ascertain how the depths of the sewers will be affected by the surface irregularities, which to a great extent govern the direction of flow, and the inclinations to be given to the sewers. To do this, levels will require to be taken along the centre of each road to be sewered, and the exact position of each sight taken, fixed by means of a continuous chain measurement; this, in addition to enabling the sections to be plotted with greater accuracy, will serve as a check upon the correctness of the general plan, and frequently prove of assistance in setting out the work later on. Whilst taking the surface levels, the property on either side should be examined with a view to their future connection.

Another point in connection with the levelling, which although perhaps appearing insignificant in itself, will prove of great convenience, as well as effecting a saving of time when the levels of the work require setting out, is the fixing of the levels of certain permanent objects (as near the ground as possible), such as door-steps, plinths of buildings, etc.; their respective values and position being so noted as to be readily found whenever required.

CHAPTER VI.

SECTIONS.

Having obtained the necessary surface levels, as well as those of any existing sewers, outlets, or any obstacles likely to affect the course of the sewers, sections may now be prepared in the usual way, all existing objects being shown in black, and all new work and those figures referring to it in red. With the road surface clearly indicated as shown on the accompanying sheet of sections *(sheet of drawings No. 3)*, we shall now be enabled to advance another step in the preparation of our scheme.

Tolwich-road.—Taking the most important sewer first—viz., that in Tolwich-road—it will be advisable to commence at the lower extremity, and select some point near the outfall, fixing the invert there at such a level as to permit of the sewage being delivered into the works, and after treatment discharged on to the land proposed to be laid out as an irrigation area.

An examination of the section will lead to the selection of the bridge over the mill stream as a suitable point from which to calculate the gradients of the proposed sewer. By placing the invert here level with the soffit of the arch, or at a reduced level of 117·00, about 2ft. 6in. will still remain available for the passage of the sewage through the works.

Following the surface undulations, and keeping the sewer a minimum depth of 8ft. 6in. at the depressed portions of the road, it will be seen that a sewer so placed would be slightly elevated about the centre of its length near Sandy-lane ; the first material change of gradient only taking place at that portion near Bridge-street. A decided improvement in the line can therefore be effected at the expense of a very little extra excavation by running the invert at one inclination from the lower end up to Market-street, and from this point up to Bridge-street, where, owing to the diminution in the quantity of sewage to be carried, the inclination may be beneficially sharpened to 1 in 300.

The remaining length up to the end of Beech-road will present no difficulty, the natural gradients enabling a good fall to be given to the sewer.

The Tolwich-road main being conveniently placed for receiving the sewage of the central portion of the town, provided the depth fixed above proves sufficient, we have still two areas unprovided for which will now require attention—viz., the district situated on the northern side of the river, and those streets on the south side—the sewage of which would naturally have a tendency to gravitate towards Mill-lane, and which could therefore with advantage be intercepted by a sewer in that road, and by this means be prevented from descending to the lower portion of the town.

Windsor-road and Elm-road Sewers.—Turning now to the sewers on the north side of the town, it is clear from an inspection of the surface levels (see contour plan) that a sewer in Elm-road would serve for those roads situated at a higher level—viz., Crescent, Padley, and Gladstone roads; likewise a sewer at the lower extremity of Windsor-road would intercept the sewers from the area above, so that for the present it is only necessary to devise a means of connecting these two sewers. There are two ways in which this may be effected—firstly, by turning the whole of the sewage from Windsor, etc., roads along Highcliff, and through the intervening strip of land, joining the Elm-road sewer in Padley-road; secondly, by continuing the Windsor-road sewer over the face of the cliff, from whence it would run westward along the river bank to whichever spot may be selected for crossing the river. Comparing these schemes, the first suggestion would involve laying the sewer along Highcliff with a fall contrary to the surface gradient, consequently a depth of 30ft. would be reached at the highest part; whereas in the second scheme, a moderate depth could be maintained throughout, and the sewer being laid along the river bank would cause less interference with private property, consequently be less likely to meet with opposition from the owners.

Adopting the latter suggestion on account of the advantages presented, we have now to determine the best point at which to join the two sewers in question; but before being able to do so will have to decide upon a means of carrying the sewer across the river.

River Crossing.—The first idea that occurs is to make use of the existing bridge; but a little reflection will show that such a course might be attended with serious results, since a sewer placed at the necessary depth in Padley-road could only pass through or under the foundations, any interference with which in the case of such a structure should be avoided. It will therefore be preferable to select another point for the river crossing.

Reference to the " general plan " shows that a suitable place exists at some little distance below the bridge, the position being also favourable to serve as the converging point for the sewers from Elm-road and Windsor-road in such a manner as not to prejudicially affect the adjacent property.

The sewer after passing the river could be conveniently connected to the main in Tolwich-road at the point shown on the plan, an advantage being gained by joining this sewer at a lower level than would have been the case had a point higher up been selected.

Levels of River Bed.—To ensure the feasibility of the above scheme, a section should now be got out on the precise line suggested ; but in this a little difficulty may be experienced in obtaining the levels of the river bed. In view of this a simple means may be described by which these may be obtained, where to take direct soundings might entail delay in the work.* Provided the width of the river does not exceed 80ft. or 90ft., attach two 100ft. chains firmly together, and at the centre point suspend a weight by means of a cord knotted at intervals of every foot ; having got the chain swung across, let it be drawn up as tight as possible until the suspended weight is directly over the edge of the opposite bank ; if from this position the chain be moved forward, say, 10ft. at a time, and at each distance the weight be

* This method was suggested to the author by Mr. J. McKie, C.E , having been used by him with much success on railway surveys.

permitted to sink until it rests on the bottom, the depths at these distances can be easily arrived at by observing the number of knots visible above the water-level.

The surface levels being plotted as shown on the accompanying plan (see Elm-road section), and placing the sewer in Elm-road at a depth of 9ft. 6in., the invert line being continued forward to the river, will be found to run out very little above the water-level, consequently there is no practical alternative but to carry the sewage across by means of an iron syphon placed under the river bed. Notwithstanding that objections are frequently urged against the use of syphons on the ground of their liability to silt up, the author is of opinion that where this has occurred it is more frequently due to incorrect design than to inherent defect. Be this as it may, whatever form of syphon is adopted, it is of the utmost importance to obtain such an amount of head as shall produce a velocity in the flow sufficient to render a stoppage almost an impossibilty. The amount available in the present case, it will be seen from the section, is dependent upon the fixed depth of the sewer at Padley-road, and at the junction with the Tolwich-road main. At the former, as already stated, the sewer is 9ft. 6in. below the surface, giving a reduced invert level of 126·50. At the latter point, allowing a 6in. drop in the main, the invert will be 123·38—the difference between the two being 3·12ft., which it is proposed to utilise in the manner shown on the section, and by which a head of 18in. is obtained on the syphon.

It may be observed that in arranging the gradients, a quicker one has been given to the length below the syphon than to that on the inlet or upper side. The reason for this is to reduce as far as possible the head on the lower outlet, so as to avoid any back pressure, which, besides tending to reduce the velocity of the flow, would reduce the discharging power of the syphon.

Storm Outlets.—In all systems of sewerage where the separate system is not adhered to, it is advisable to provide for the discharge of excessive volumes of storm water, which at rare intervals during heavy storms finds its way into the sewers through the road gullies, and which, if not permitted to escape, would require sewers of enormous capacity to deal with it. With a view to providing such outlets, it will be seen on referring to the Tolwich-road section that a suitable place exists at the point where the sewer crosses the mill stream ; the position being such that an overflow properly designed would prevent any excessive quantity of sewage from passing into the works. In the same manner by placing a storm overflow at the inlet end of the river syphon, the sewers on the north side will be relieved prior to their discharge into the main sewer.

Leaving further details of these and other practical questions affecting the scheme for further discussion in a later chapter, in which it is proposed to give a few working details to scale, we will now proceed to complete the sewer gradients on the north side.

Windsor-road.—The connecting portion of this sewer—from the lower end of Windsor-road—to the chamber into which it discharges at the inlet end of the syphon, being necessarily placed very near the surface, it will be advisable to provide against injury to the pipes by the formation of a bank of earth over the line of sewer. At the foot of the cliff, owing to the sudden drop from Windsor-road, a special form of chamber will have to be designed ; but from this point upwards the sewer may be carried through at normal depths, with good gradients as shown on the section.

Mill-lane and High-street.—This sewer, in addition to the property which it directly serves, will intercept the sewage from those roads situated to the south of it, the whole being conveyed and discharged into the Tolwich-road main at a chamber placed at the junction of the two sewers. The invert level at this chamber will be found from calculation to be 118·99 after allowing a drop of 9in. into the main. Owing to the depression occurring in Mill-lane about 120 yards from the lower end, a gradient of 1 in 350 has been used in order to obtain a sufficient depth near the mill, but from here upwards no difficulty will be met with in obtaining better inclinations.

Having laid down the gradients of the principal sewers of the town in such a manner as to enable the branch sewers to be laid and connected in an efficient manner, a stage has now been reached when it will be necessary to calculate the volumes of sewage to be conveyed together with the diameters of the pipes.

CHAPTER VII.

VOLUME OF SEWAGE.

Without entering upon the chemical constituents of different qualities of sewage, such investigations being of more practical importance to the chemist than to the engineer, sewage may be broadly classified under two heads: (1) domestic sewage, consisting principally of refuse water from sinks, together with that used for flushing and cleansing purposes; (2) liquid refuse produced in certain trade processes—such as dyeing, bleaching, papermaking, etc.—which, in addition to its foulness, in large works may be discharged in such quantities as to render special provisions necessary. A third and most important item to be considered in the sewering of a town is that portion of the rainfall falling on the surfaces of roads, yards, roofs, etc.; and a further quantity, which, being absorbed by the ground, may under certain conditions require specially dealing with in order to prevent it from entering the sewer in excessive quantities, and in doing so causing damage to the work.

Combined and Separate Systems.—Here, then, the question will arise as to the conditions under which surface and subsoil water may be admitted into the sewers. Notwithstanding that this has long been a debateable point amongst engineers, on nearer investigation it will generally be found to resolve itself into a question of cost—the saving effected by utilising one set of sewers for both the foul sewage and the surface water being compared against the benefits that might be derived from separating the two classes of liquid. In the first instance, a sewer to take the greatest volume of surface water in storm time would require to be of very large capacity, and which, if allowed to reach the works, would require tanks several times larger than what would amply suffice for the ordinary flow, besides adding the cost of treatment when chemicals were used, and necessitating a larger area of land for its purification. Where the sewage has to be pumped, such a large increase would require more powerful machinery to cope with it, which for the greater part of the time would either stand idle or be worked to a small proportion of its full strength. In such cases it will therefore be a distinct advantage to exclude large volumes of surface water, thus rendering the quantity to be raised as constant as possible.

In the separate system several advantages would be obtained by keeping the foul sewage distinct from the clearer liquid. But to apply this principle in its entirety has been found to be almost an impossibility, necessitating a duplicate system of sewers throughout, the cost of which would seldom be sanctioned; and further placing an excessive burden on the property owners, who would be put to the expense of laying down a double set of drains where, under ordinary circumstances, one would be sufficient. The greatest difficulty, however, would present itself when the foul and clear water drains came to be connected to their respective sewers, and which, to prevent mistakes occurring, would entail constant supervision on the part of the authorities. There are, however, special circumstances in which a local authority might be justified in adopting a separate system of sewerage, as, for instance, in the case of a seaside town, the sewers of which would be tide-locked for part of the day; or, again, in towns where old defective sewers might be utilised as surface-water sewers without augmenting the cost of the new scheme. Such a system might also be adopted in dealing with water-logged localities, where, by lowering the subsoil water, a decided improvement in the sanitary state of the place would result.

Except in a few such cases, it will generally be found preferable, in dealing with an ordinary town, to adopt an intermediate course—viz., to admit into the sewers that portion of the surface water due to light rainfall, which, as previously stated, may be almost equal in foulness to ordinary sewage; whilst excessive volumes in storm times may be discharged into the natural watercourses by means of specially-arranged overflows placed at convenient points in the system. The main objection that may be urged against this principle is that a portion of the sewage is discharged with the storm water into the streams. But experience has shown that no serious pollution results from such a course, the sewage being diluted to a great extent in the sewer, and still more so when it passes into the watercourse, which at such times would be in flood and far exceeding its normal volume. Adopting this method in dealing with the town selected as an example, it now remains to be determined how it may be practically applied.

Domestic Sewage.—Taking first the sewage proper, it has been found that the amount produced is dependent upon the consumption of water, being greater in towns with a constant service than where springs and wells constitute the sole supply. The amount of water supplied per head per day may therefore without sensible error be taken to represent the daily flow of sewage. Owing to the discharge varying during different periods of the day, the maximum hourly flow is generally arrived at by assuming one-half the total quantity per day to be discharged in six hours.

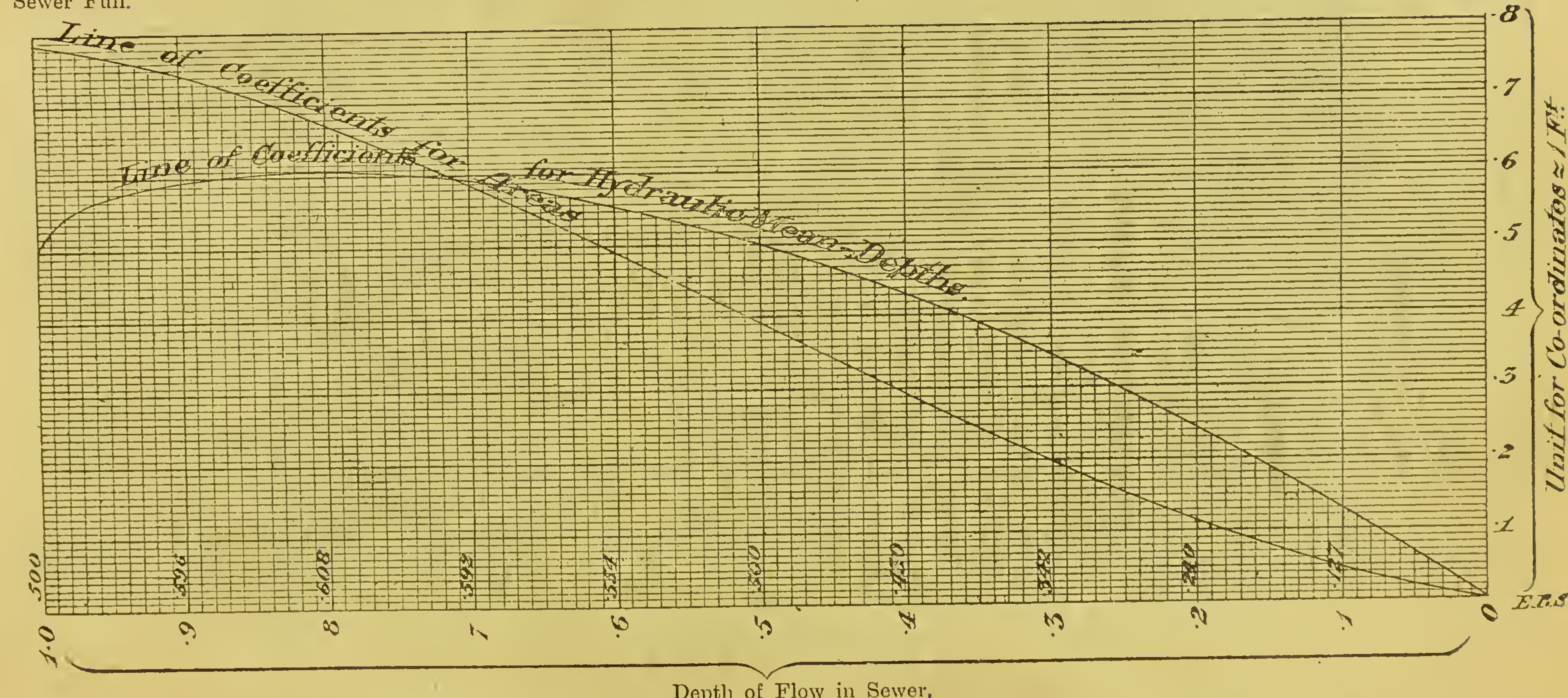
Trades Liquid Refuse.—This quantity, it is apparent, depends entirely upon the description and the number and size of the works producing it, and can only be arrived at by calculation of the issuing streams or from enquiries as to the quantities of water consumed. In order to show the effect that such works may exert on a sewerage scheme, a mill has been shown on the "general plan" (*Sheet 1*) situate at the lower end of Mill-lane, the discharge assumed being 14,400 cubic feet per day, which represents the actual volume from one dyeworks with which the author had to deal.

Surface Water.—It has been found from experiments that in thickly-populated towns with paved surfaces from two-thirds to three-quarters of the total volume in heavy rainfalls finds its way into the sewers. Taking 4in. per day as the maximum rate of rainfall of sufficient duration to reach the sewers, two-thirds, or 2·6in., per day may be taken as the extreme quantity that will ever require to be dealt with in such cases. In country towns and suburban districts, owing to the more absorbent surfaces upon which it falls, one-third the maximum rainfall, or 1·3in., will prove ample, whilst in rural districts from $\frac{1}{8}$in. to $\frac{1}{4}$in. per day would be as much as need be allowed for.

Population.—In calculating the amount of sewage proper according to the water supply, provision should be made for such an increase in population as may reasonably be expected to occur during a period of, say, 25 or 30 years. In computing this increase, the census returns for the last 10 years may be consulted, and an opinion formed as to the same rate of increase being continued, at the same time taking into account such probabilities as the extinction of existing, or the formation of new industries. Assuming in the present case that 40 per cent. increase of population will take place on the northern or residential portion of the town, and 33 per cent. in that of the south side, the total volume of sewage proper will be as shown in the following table.

District.	Present population.	Probable increase of population	Population to be provided for.	Cubic feet per day, at five cubic feet per day water supply.	Cubic feet per minute at rate of half daily flow in six hours.	Cubic feet per minute.
On N side	1,450	40 per cent.	2,030	10,150	14·1	} 50·6
,, S ,,	4,200	33 per cent.	5,266	26,330	36·5	
,, S ,, Effluent from mill, 14,400 cubic feet per day discharged in eight hours						30
,, N ,, Surface water on 50 acres due to 1·3in. per day						168
,, S ,, Surface water on 80 acres due to 2in. per day						403

DIAGRAM FOR HYDRAULIC MEAN DEPTHS AND AREAS.



For Hydraulic Mean Depth.
H.M.D. = R × *c*.
R = Radius of Pipe in Feet.
c = Coefficient from Diagram.

For Area of Fluid.
A = D^2 × C.
D = Diameter of Pipe in Feet.
C = Coefficient from Diagram.

CHAPTER VIII.

DISCHARGE OF SEWERS.

In sewer calculations, owing to the variable conditions under which the discharge takes place, extreme accuracy is not to be obtained, since according to the experiments of D'Arcy, Bazin, and Kutter, the difference in the material or in the workmanship of the sewer would exert an appreciable difference in the discharge. Moreover, it is evident that the slightest irregularities in the form of the pipes, or any accumulation of deposit, at any point would be sufficient to upset the most refined calculations.

Formulæ.—The best known, and perhaps on account of its simplicity that most generally used, is one of Eytelwein's, and which although in certain sizes of pipes fairly correct, still it is not to be relied upon for all sizes. The form in which it is most convenient for ordinary use is

$$V = 55 \sqrt{r \times 2f},$$

in which r = hydraulic mean depth;
f = fall in feet per mile;
V = velocity in feet per minute;
and from which, the velocity being known, the quantity discharged in cubic feet per minute,

$$Q = V \times A,$$

A being the sectional area of the fluid in feet.

Prof. Weisbach, in his later researches into the laws governing the motion of fluids in channels, found from the result of 255 experiments that the frictional resistance did not increase as the square of the velocity, as assumed by Prony and Eytelwein, but in a slightly different ratio, a different coefficient of friction being used according to the velocity ("Lehrbuch der Theoretischen Mechanik").

To obtain the discharge in open channels or sewers, he first makes use of an approximatory formula differing little from Eytelwein's, and from which he obtains the velocity in feet per second,

$$V = 91{\cdot}56 \sqrt{r s},$$

r being the hydraulic mean depth ;
s ,, sine of the inclination or fall divided by the length of the channel in feet.

Having got an approximate value for V, he makes use of this to obtain the correct coefficient of friction by means of the following formula :

$$C = 0{\cdot}007409 \left(1 + \frac{0{\cdot}19208}{V} \right),$$

and using the value of C obtains the velocity in feet per second as follows :

$$V = \sqrt{\frac{64{\cdot}4\, r s}{C}},$$

r being, as before, the H.M.D.,
s ,, the sine of the inclination.

It will much facilitate the working of the above formula if a table be prepared showing the coefficients of friction for those velocities mostly occuring in sewer work, say, from 6in. per second up to 6ft. per second, and which can then be referred to on obtaining the approximate value of V.

Since in all these formulæ relating to the flow of water in channels the hydraulic mean depth and the sectional area of the fluid has to be calculated, which of itself, except in the case of pipes half or fully charged, involves considerable time, the author has prepared the diagram (page 44), which will enable both the H.M.D. and the areas to be obtained in a very simple manner, and sufficiently accurate for ordinary sewer calculations.

To make use of the diagram, say, for a pipe two-thirds full, it is only necessary to take a point on the axis at ·66 of the length, and from this to measure up to the respective curves; the coefficients in this case would be found to be ·581 and ·558 for the H.M.D. and area respectively, the values of which for any sized pipe may be found by the formulæ given. In a similar manner the H.M.D. and areas for any other depth of flow can be obtained.

CHAPTER IX.

SIZE OF SEWERS.

Having adopted certain gradients in the sewers, it has now to be ascertained what sized pipes will be necessary to discharge the volumes already calculated.

Commencing first with the quantity passing into the storm-overflow chamber on the north side of the river, where the two sewers from Windsor-road and Padley-road unite, the volumes conveyed by each will be in proportion to their relative drainage areas, or about 1 to 2, from which the respective discharges will be found to be 60·7 and 121·3 cubic feet per minute. The total volume, if allowed to pass the syphon, would more than fill a 12in. pipe in that length between the river and Tolwich-road, at the inclination of 1 in 200, as shown. But owing to the bulk of this quantity being at such times comparatively pure, a considerable reduction may be effected by a properly arranged storm overflow on the north side, so designed that as soon as the sewage becomes diluted to three times its volume, any further quantity, instead of passing into the syphon, is carried into the river by a side outlet. The dry-weather flow being 14 cubic feet, 42 cubic feet per minute will be that proportion retained in the sewer, leaving 140 cubic feet to be discharged into the river. To deliver

42 cubic feet through the last-mentioned length of sewer, a 9in. pipe would under ordinary conditions be sufficient, but it will be advantageous to adopt a larger size, say, 12in., and by so doing reduce the head on the outlet end of the syphon.

Dealing in a similar manner with the storm overflow on the southern side near the outfall, the maximum volume delivered in storm time will be 412 cubic feet, including the 42 cubic feet from the northern sewer. Allowing the 69 cubic feet of sewage contained in this amount to be diluted, as before, to three times its bulk, 207 cubic feet will pass into the works, and the remaining 205 cubic feet be discharged into the stream.

From the above figures it will now be possible to fix the diameter of the main sewer from Mill-lane to the storm outlet. The gradient being 1 in 403, an 18in. pipe two-thirds full would discharge 230 cubic feet per minute against 412, the quantity required. Under similar conditions a 24in. sewer would discharge 480 cubic feet per minute. It will therefore be safer to adopt the larger size for this short length, making it a brick sewer 24in. diameter.

Taking another case—viz., that portion of the sewer in Mill-lane below the mill, the maximum volume here will be found to be 165 cubic feet, including the mill effluent; and since a 15in. pipe two-thirds full at the gradient shown discharges 158 cubic feet, this size may be adopted as sufficiently near for practical purposes.

Having thus fixed the diameters of the two most important sewers, it will be unnecessary to pursue these calculations further as regards the other sewers, nor, indeed, will it be found necessary to do so in the case of the smaller branch sewers, since in the majority of these experience will at once show that a sewer 9in. diameter, being the smallest size recommended in practice, would deliver more than can possibly reach it.

DETAILS (Sheet No. 4).

Concurrently with the gradual development of the scheme, and as the various phases have been reached, several methods may have suggested themselves for dealing with the sewage at different points in the system.

From such ideas being, in the first place, little more than vague indications of what course might be adopted, they will as the work advanced have probably assumed more definite forms, until now it only remains to draft them out in such a practical manner as shall enable the work to be correctly specified, and the quantities computed. In preparing the details, needless to say, simplicity and clearness are the main *desiderata*, since without these the intentions of the designer cannot but fail to be conveyed to those tendering for, and subsequently carrying out the work. Moreover, want of clearness and inaccuracies should be regarded as one of the most frequent sources of misunderstandings and disputes between the engineer and the contractor. For this and other reasons, it will be seen how important it is that no details come into the hands of a contractor tendering for the work unless they be in every respect thoroughly practicable ; it being even preferable, should any doubt whatever exist as to any special question of construction, to have the opinion of a practical man, rather than, as frequently happens, to have to alter the designs when perhaps the work is partially completed.

SCALE FOR DETAILS.

For ordinary sewer details—such as manholes, lampholes, etc.—a scale of ½in. to the foot will generally prove sufficiently large, provided that details of ironwork be separately shown to one-quarter or even one-half full size. For more intricate portions of the work, 1in. to the foot may have to be adopted in order to enable the courses of brickwork being accurately shown, a necessity frequently arising where stone or ironwork is used in conjunction with brickwork. Notwithstanding that drawings should be so prepared as to allow of scaled measurements being taken, too much reliance should not be placed on these, but all main dimensions clearly figured on the working drawings. Referring again to the plans and sections (*Sheets* 1, 2, *and* 3), it will be observed that the most important points in the scheme calling for special treatment, and which it is proposed to illustrate and discuss, are as follows:

A. Sewer crossing over mill stream near outfall.

B. Storm-overflow chamber near outfall.

C. Manhole at junction of Tolwich-road and Mill-lane sewers.

D. Manhole at junction of High-street and Market-street sewers.

E. Ordinary lamphole and ventilator on straight pipe sewers.

F. General arrangement of river crossing.

G. Flushing apparatus, screening chamber, and storm overflow on north side of syphon.

H. Inspection chamber and scour-out on syphon.

I. Manhole at outlet end of syphon.

J. Fall pipe in sewer at lower end of Windsor-road.

Sewer Crossing over Bridge near Outfall.

Detail A.

This is a case frequently occurring in sewer work where one sewer has to be laid across an existing sewer or culvert, and in which it is of importance to keep the uppermost sewer as low as possible. This may be best effected by making use of a special cast-iron saddle, so formed that the underside is curved to the same radius as that of the arch in which it is to be fixed; and in a similar manner the upper side made to form either part of the invert of the upper sewer or U-shaped in section, the pipes being laid in the space, as shown in the detail, with a small clearance to allow of settlement. In designing such a saddle the necessity of plenty of strength in the side webs should not be overlooked, since without this fracture must inevitably take place across the centre on any pressure bearing upon it. If placed in such a position as not to be subject to the heavy road traffic, and for a casting of the size shown, $\frac{5}{8}$in. thickness of metal will be sufficient, allowing an extra $\frac{1}{8}$in. in the webs, which will further be materially strengthened by thickening the upper edge so as to form a fillet. If designed to be placed under the carriageway, an additional thickness of $\frac{1}{8}$in. may be given throughout. All hollows in the casting should be well packed with concrete to prevent accumulation of water.

Storm Outlet into Mill Stream.

Detail B.

A simple arrangement for diverting excessive volumes of storm water, and one which has been adopted with much success in sewer work, is that devised by the late Mr. Bateman, C.E. Taking advantage of the natural law by which a column of water issuing from an orifice is projected to a greater or less distance according to its velocity, a drop of several inches is given to the sewer, immediately beyond which is an orifice from which the foul sewer is continued at a lower level; the upper sewer is also continued beyond the orifice, acting as a relief sewer and discharging into any available watercourse.

With an arrangement of this kind correctly designed, the whole of the dry-weather flow having a normal velocity passes into the opening, whilst on the velocity being increased by the influx of storm water, the fluid is either partly or entirely projected over the opening, passing onward to the point of discharge.

This arrangement not being adaptable in the present case owing to the levels, another form of overflow is shown, which for large-sized sewers possesses certain advantages over the last. It consists, as shown, simply of a weir formed in the side of the sewer, over which a portion of the sewage in storm time passes and is discharged as before. To ensure the successful operation, considerable judgment is frequently necessary in fixing the height of the overflow sill. Some engineers consider that this should be such that discharge only commences on the sewer becoming almost fully charged. Now, looking at the fact that in most new schemes the sewers are designed of a size considerably in excess of present requirements, and that the volume of sewage is likely to be an ever-increasing quantity, either the height of the sill should be variable or some method devised by which a similar result is obtained. This may be simply effected by throttling the outlet sewer either by means of a half gate or one length of small-sized pipe inserted in the sewer, which on the flow being increased may be removed.

With ordinary gradients, the author is of opinion that an overflow sill will work best when placed at about two-thirds of the height of the sewer; if, however, on a quick gradient where the diameter of the sewer is probably much greater than necessary, the height should not only be materially reduced, but the length of the sill increased.

Manhole at Junction of Tolwich-road and Mill-lane Sewers.

Detail C.

Notwithstanding the greater strength and compactness obtained by using circular manholes, the old square form may under certain conditions be retained with advantage, as will be found in dealing with the converging sewers at the point named. The general arrangement being clearly shown, brief reference need only be made to those points not explained in the drawing. Regarding the best method of connecting the pipes with the brickwork, there are several ways in which this may be effected: firstly, by simply building the pipe into the brickwork and turning a small arch over to prevent the weight damaging the pipe; secondly, by inserting a stone block rebated at the back to receive the pipe, and worked at the face either flat or curved according to the brickwork; thirdly, by similar blocks as the last, but made in stoneware, which, being less absorbent than stone, may be preferred from a sanitary point of view.

The first method, although answering well where the pipes enter at right angles, or nearly so, to the face of the brickwork, does not make a good job where an oblique junction is required, the bricks of the arch having to be laid so as to form what is known as "dog toothing" on the face, which greatly detracts from the appearance of the work. In such cases stone blocks should be used possessing the advantage that they can be readily cut to any form required. For blocks of 12in. and upwards it will much facilitate working and handling if they be made in two separate halves, the horizontal joint being at the centre.

The outgoing sewer at this point being 24in. diameter, is shown formed in one-half brick ring of specially radiated bricks, seven courses in the invert being hard Staffordshire blues, and the remainder good reds.

For the purpose of access to the manhole, as well as affording the necessary ventilation, a strong but simple form of perforated cover should be used, avoiding any complicated locking arrangements which are, as a rule, soon rendered useless by rough treatment and the accumulation of dirt and rust. Beneath the cover, and suspended by hooks or a cross-bar, a galvanised-iron dirt-box should be provided, in order to prevent sticks and dirt dropping direct into the sewer.

Manhole at Junction of High-street and Market-street Sewers.

Detail D.

This form of manhole has, on account of the simplicity of its construction and accessibility, been selected as the general type throughout the scheme. The brickwork, it will be seen, is carried up vertically of the full diameter to within 6ft. of the surface, from which point the width is evenly reduced until a clear opening of 2ft. diameter remains at the top. To make a thoroughly good job of the brickwork, stretcher bricks of two different radii should be used—one size working to the lower portion of the manhole, the other from about 4ft. from the surface to the underside of the stone flag. In addition to these, specially radiated headers should be provided both at the course where the batter commences and at the finishing course, the object in both cases being to keep the bed joints perpendicular to the face of the brickwork, and at the top course horizontal to receive the stone.

Lamphole and Ventilator.

Detail E.

For small towns with ordinary traffic, a lamphole of the form shown will be found to answer satisfactorily.

To prevent any weight passing over the cover being transmitted to the lamp-shaft and damaging the sewer, the upper end of the 9in. pipes should be kept some distance clear of the surface, and a pipe of larger diameter placed over the end socket downwards ; the upper end being rebated into and supporting the flag upon which the cover rests. In manufacturing towns it will be advisable to adopt a more substantial foundation of brickwork or concrete in lieu of the above arrangement.

River Crossing.

Detail F.

Without sufficient regard being paid to the conditions under which it has to act, the form of syphon usually adopted as a means of conveying the sewage under the bed of a river or stream consists simply of a brick shaft on each bank, the two being connected by a straight length of iron pipe laid at the necessary depth.

Such an arrangement, although working satisfactorily on a main outfall sewer of large diameter with a constant flow of sewage, is undeniably defective if applied to small pipe sewers. This is, in the first place, due to the fact that the area of the shaft up which the sewage rises being many times larger in area than that of the sewer, the velocity of the sewage, instead of being increased, is suddenly so reduced that solids in suspension, which should have been carried forward, are precipitated, both obstructing the flow and causing a nuisance if allowed to remain.

To overcome this defect, an arrangement is shown in which it will be observed that from the inlet chamber the iron pipes are reduced to 8in. diameter.

On passing into the second chamber, instead of simply delivering into this, it is carried through, and from this point rises by an easy gradient to a third shaft at the necessary level. From the point where the pipe commences to ascend, by further reducing the diameter, a sufficient velocity can be obtained to render any stoppage unlikely.

As a further precaution, and in order to obtain the full effect due to the head, which would give a scouring velocity of upwards of 4ft. per second, special means have been devised, which will be separately described.

Flushing-tank and Storm Outlet.

Detail G.

Although in a system of sewers the main object should be to effect the removal and not to retain the solids contained in the sewage, the present case will be seen to furnish an exception to the general rule, inasmuch as it is a necessity that all such articles as broken bottles, tin cans, etc., frequently brought down by the sewage should be removed by screening before its admittance into the syphon. For this purpose, the sewage on issuing from the pipes passes first through an outer chamber in which the heavier solids are retained; it then passes through a circular opening over which is placed a movable iron screen to effect the removal of coarse floating matter, discharging into a second chamber so constructed to act, as it were, like a funnel inlet to the syphon.

Behind the screen, for the purpose of diverting the sewage during the cleansing or inspection of the syphon, a 12in. regulating penstock is shown, whilst on the outlet end of the short length of connecting pipe a lightly-hung double-hinged flap is placed. Forming part of the inlet chamber, but placed at a higher level, is a clear-water tank for flushing out the syphon periodically. The water supply may be either obtained direct from the pressure main, as shown, by a $\frac{3}{4}$in. lead service pipe, a stop-cock being provided at the tank inlet for regulating the flow, and accordingly the number of flushes; or if no such source be available, and the levels admit, the river water may be utilised by being brought down from a point higher up stream.

To enable the tank to discharge its contents when full, a 6in. automatic flushing syphon is shown, the outlet being as near as practicable to the inlet end of the river syphon, and the water at each flush being prevented from flowing into the screening chamber by the flap valve already mentioned.

The form of syphon considered most suitable under the circumstances is that of Messrs. Adams and Co., which is too well known to require any detailed description; suffice it to say that it possesses one advantage over most other forms of flushing syphons by not requiring any special seal arrangement on the discharging leg. Another feature of this syphon is that by a special arrangement the water rises to a considerable height above the bell before the discharge takes place, thus giving extra force to the flush. The action of the syphon being due to the pressure of the atmosphere on the water in the tank, it is essential that a perforated cover be used so as not to impede the movement of the air.

Taking advantage of the proximity of the river at this point, and the suitability as regards the level, the sewer can be efficiently relieved of any excess of flow in storm time by forming one of the walls of the screening chamber to act as a weir in the manner previously described, the surplus volume passing along a brick culvert of special form and discharging into the river at flood-water level. As a precaution against any further rising of the river, as well as to prevent vermin from entering the sewer, a flap should be placed on the outlet.

Inspection Chamber and Scour-out.

Details H *and* I.

The only point not clearly shown on the detail, and for which explanation may be necessary, is the construction of the inspection box placed, as will be observed, at the lowest point in the syphon. The cover of this, instead of being a simple plate, is so formed on the underside that when fixed in position and bolted up, no alteration in the area of the waterway takes place, the pipe being, as it were, continuous, without any enlargement to impede or reduce the velocity of the flow, and which might give rise to stoppage.

For the purpose of periodically scouring out the syphon without interfering with its working, a 3in. conical cock is placed on the underside of the inspection box.

Arrangement for Drop in Sewer at Lower End of Windsor-road.

Detail J.

In order to avoid excessively steep gradients, which tend to the premature destruction of the sewer, it is frequently advisable to allow a considerable drop from the sewer into the manhole. On ordinary sewers this may be effected by an arrangement similar to that shown in the detail, or if stoneware pipes be substituted for iron, they should be solidly bedded and enclosed in concrete. Where portions of the pipes are exposed, iron may be beneficially employed.

CHAPTER X.

PRECIPITATION WORKS.

The works previously described having been designed with a view to the speedy and uninterrupted conveyance of the sewage from the points where it enters the public sewers to a site already selected on account of its general suitability for its purification, it now remains to be determined by what means this last and most important object is to be attained. Before proceeding to the discussion of this question, it may be well to make a slight diversion and to review as briefly as the subject allows some of the main features in connection with sewage purification as actually practised, disregarding for the present the later and more scientific treatments as that by electrolysis or by bacterial agency—processes which, although perhaps destined to greatly modify, if not to entirely revolutionise, existing theories, can as yet be scarcely regarded as sufficiently developed to be applied by engineers in dealing with the sewage of towns.

Application of Crude Sewage to Land.—In the earlier attempts at sewage purification, the liquid was usually discharged in its crude state on to land under cultivation, and according to the nature of the soil would be either absorbed or would pass over the surface, ultimately to find its way into the nearest ditch or watercourse. Experience, however, soon taught that, owing to the large quantity of insoluble matter brought down by the sewage in a state of suspension, and which, by covering the surface with a layer of slimy mud, soon rendered it almost valueless as a purifying medium, such a system could only be practised successfully where an almost unlimited area of land was available, and which thus enabled a very small proportion of the total area to be irrigated in order to afford the remainder a sufficient period of rest to regain its normal condition after each application of sewage.

Separation of Solids.—Recognising, therefore, the decided advantages to be gained by the separation of the greater part of the solid from the liquid portion of the sewage, engineers and chemists have for years past devoted themselves to the discovery of a cheap and yet effective means of bringing this about. In the older examples of sewage-disposal works, simple precipitation was the method employed, the sewage before passing on to the land being first admitted into a brick or concrete tank, through which it flowed either continuously at such a low velocity that subsidence took place, or intermittently into two or more tanks, each one on being filled being allowed a certain period of absolute rest, the sewage in the meantime being turned into another. After a sufficient time had elapsed, the effluent was in the latter case drawn off each tank successively and passed on to the land. The main difficulty in connection with this system arose when large volumes of sewage required to be treated, the slowness with which precipitation took place necessitating the construction, on the one hand, of either a very large tank, or if on the intermediate principle of several smaller ones, but still of sufficient capacity to impound the entire flow for a period of several hours. In order to hasten and assist precipitation, as well as to render it more perfect, various materials and chemicals have been tried in combination with the sewage, but for the most part have failed, those yielding the best results being rendered almost prohibitive as to cost when applied in sufficient quantity to bring about the desired result.

Lime Treatment.—Of the many precipitants tried, ordinary lime has been, and perhaps still continues to be, one of the most extensively used, notwithstanding the existence of certain serious objections to which reference will be made later. In making use of lime as a precipitant, considerable care is necessary first in the selection of a suitable quality, only the purest limes being found to yield good results. The preparation of the lime previous to its application to the sewage is also a matter of importance, and is usually carried out in the following manner: After being slaked in the usual way it is lifted either by hand or by a suitable arrangement of elevators into specially-designed mixers, where, with the addition of a small quantity of water or sewage, the whole is reduced to a creamy consistency by the combined action of revolving arms and metallic faces, the latter rendering important service in reducing any unslaked particles or lumps to the necessary degree of fineness. In this state the mixture is now added to the sewage as it enters the works, the whole being thoroughly agitated by properly constructed tumbling bays or by the action of revolving arms partially immersed in the liquid. The sewage being passed into the tanks, rapidly begins to clear itself; and if designed on the " absolute rest " principle, after about two hours, precipitation will have so far taken place that the effluent can be drawn off from the surface by floating valves as a clear, odourless liquid. With due care, such an effluent should with ordinary sewage present an almost colourless appearance when held to the light in a tumbler, and should appear to be free from any suspended matter. Notwithstanding, however, its apparent purity, a lime effluent of this description is found on analysis still to contain a large quantity of putrescible matter, and is therefore to be regarded as totally unfit for admittance into any but tidal waters unless first subjected to some further process of purification.

Coke Filters—Thus it will be found that coke and other artificial filters are frequently used in conjunction with the lime process, the idea having been held by many engineers that these possessed sufficient oxidising powers to dispense with the use of land as a purificant. It should, however, be borne in mind that the Local Government Board do not hold this view, but insist on land filtration where possible.

Sludge—Perhaps the most serious objection to the lime treatment is the large quantity of sludge produced, and, particularly in the case of large towns, the difficulty connected with its satisfactory disposal; this is due principally to the large percentage of moisture (about 90 per cent.), which renders it almost valueless to the farmer, and causes it, if allowed to accumulate on the works to any extent, to give rise to a nuisance. In small works the sludge may be dealt with in the following manner: The sewage in the tank being run off as low as possible without disturbing the sludge, it may be lifted either by means of a chain and disc pump and conveyed along wooden shoots to a concreted bed in the vicinity of the tanks, there to drain and part with some of its moisture, the foul liquor being returned into the tanks for re-treatment; or, if the levels permit of sufficient fall being given, the sludge may be drawn off direct by gravitation from the bottom of the tank and delivered at any suitable spot. After being allowed to partially dry—in doing which it will be found to have parted with about 15 per cent. of its moisture—the sludge may be ploughed into the land or otherwise disposed of. Greater difficulty, however, will be experienced in dealing with large quantities of sludge, which if deposited on the land would soon reduce the area available for irrigation to such an extent that a large quantity would have to be specially acquired and set aside for this purpose alone. Under these circumstances the adoption of filter presses becomes almost a necessity, since by their use the sludge may be reduced to solid cakes of about one-fifth the original weight—thus not only facilitating its removal, but being in this form much preferred by farmers for manurial purposes.

Having in a somewhat cursory manner described the general working of what may be regarded as the fundamental type of many of the later processes, it is not proposed to proceed any further in this direction, but to consider the practical application of one of these such as might under certain circumstances be adopted in treating the sewage of a small town. To do this, and without in any way wishing any inference to be drawn as to its comparative superiority over other processes, the author has selected for the sake of illustration as one of the simplest in its method of application that already well known as the aluminoferric process, which, although in some respects resembling the lime treatment, possesses many advantages, and appears to have given satisfactory results generally.

Aluminoferric Process.—The process, as will be seen below, derives its name from the application of a chemical precipitant, two important constituents of which are alumina and iron. In the ordinary form in which it is applied it is found on analysis to be composed as follows:

Alumina (soluble)	14·00	per cent.*
Peroxide of iron............................	·75	,,
Sulphuric acid in combination with above bases	33·81	,,
Free acid..	nil.	
Water	51·44	,,

The alumina, as Dr. Tidy remarks, possessing the property of fixing the ammonia and phosphoric acid, thus retaining the fertilising elements of the sewage—another important property being that of combining with and precipitating the organic matters contained in the sewage, which are carried to the bottom in the from of a dense curdy precipitate, leaving a clear and

* The manufacturers, Messrs. Spence and Sons, guarantee not less than 46 per cent. of sulphate of alumina.

inodorous liquid still retaining a large proportion of the oxygen originally contained in the sewage. In small works the "aluminoferric" is most conveniently applied to the sewage direct in the form of slabs 21in. long, 10in. wide, and 4in. thick, the substance having somewhat the appearance of alum, but with a faint brown tint, this being, it is stated, a guarantee of the non-existence of free acid. In large works, greater economy can be attained and the quantity to be applied better regulated to suit the variations of the flow of sewage by first placing the cakes in lead-lined tanks, to which sufficient water is added to bring the mixture to the point of saturation; the outlet from the tank can then be automatically regulated by means of a float attachment so arranged as to vary according to the volume of sewage entering the works. Notwithstanding the economy effected by this latter arrangement, the simplicity of the first method possesses its advantages, there being no mechanical contrivance to get out of order—in fact, the only attention necessary is that of renewing slabs once or twice a day as they become dissolved.

Mixing Tank.—Adopting the simpler means as being most applicable in the present case, reference to the accompanying sheet of details (*Sheet* 5) will show clearly the construction of a simple form of mixing tank. In it the alum cakes are placed on edge in an iron cradle, the bottom being sloped so that with a diminished flow, such as occurs in drought or during the night hours, only one or two of the slabs are slightly immersed in the sewage; as, however, the flow increases, one after another of the remaining slabs are exposed to the erosive action of the liquid, thus in a simple and automatic manner causing the amount of alum cake dissolved to vary according to the volume of sewage to be treated. Placed just below the alum cage are shown a series of baffle plates formed of sheet iron or slate, which being inclined to the direction of the flow produce sufficient agitation to cause the alum to mix evenly and thoroughly with the sewage.

Regulating Penstocks and By-pass.—In order to regulate the amount of sewage passing into each tank, or to cut off either separately as occasion arises, two penstocks are shown at the outlet end of the mixing tanks, whilst by closing down another on the inlet the sewage may be entirely prevented from entering the works, the effect being to put the short length of iron pipe from this point up to the bridge under pressure, the sewage then rising to such a height that discharge takes place at the storm outlet placed at this point.

Tanks.—In calculating the dimensions of the tanks it should be borne in mind that provision need only be made for the present population, any large increase in the latter being met by extending the tanks as required. In addition to the sewage proper, surface water must, in the case where the combined system is proposed, be also provided for, a further margin being allowed to enable either of the tanks to be thrown out of use periodically for cleansing purposes. Taking about two hours as the time necessary for precipitation and making allowance for the above circumstances, the tank space will be found to amount generally to from

35 to 50 per cent. of the total dry-weather flow, any less provision necessitating the tanks being hurriedly worked to the detriment of the effluent. Taking, therefore, 40 per cent. of the dry-weather flow as the tank space sufficient to meet the present requirements, this has been obtained by placing two tanks alongside each other, a compact and yet simple arrangement which for small works has in the author's opinion not yet been improved upon.

The general form of the tanks being decided upon, before proceeding to consider those minor details upon which to a great extent depend the success or otherwise of the process adopted, regard should be paid to the important chemical changes brought about by the addition of the aluminoferric to the sewage.

Immediately on entering the tank the solid matter will be observed to separate itself in the form of dense curdy masses, which, being of a higher specific gravity than the surrounding liquid, are for the greater part precipitated at no great distance from the inlet; the remainder, being lighter, remaining in suspension for a longer period, and therefore carried forward at a low velocity and gradually deposited in diminishing quantity as the outlet is reached. If the process has been successful the liquid at the latter point near the surface should now be sufficiently free of suspended impurities to enable its being discharged without detriment on to the land. In designing tanks on the "continuous flow" principle, the reasons will now be apparent for not only increasing the depth at the inlet end so as to provide for the accumulation of a moderate quantity of sludge during the intervals between the times of cleansing, but also for allowing a sufficient depth—viz., about 4ft. 6in.—at the outlet end, the sludge not being then liable to disturbance due to the movement of the effluent as it leaves the tanks.

The advantage will also now appear of subdividing each tank in such a manner that one or more divisions nearest the inlet—where, as already stated, the most deposit occurs—may be cut off from the remainder, so as to enable them to be emptied separately for the purpose of more frequent cleansing. Referring to the tank details already given (*Sheet* 5), but little further explanation will be necessary to show how the conditions mentioned have been provided for. Each tank, it will be seen, is subdivided into three equal divisions by cross walls 18in. thick, the upper edge consisting of a stone coping at such a level as to allow of the sewage passing over in a thin stream, thus leaving the lower strata of the liquid undisturbed.

At the centre of each cross wall, in preference to a circular orifice near the bottom closed by a penstock as frequently used, an opening is provided extending the full depth of the tank, and of a sufficient width to enable those occupied in cleansing the tank to pass with facility from one section to another whilst sweeping down the sludge along the central channel towards the outlet specially provided at the deepest end.

During the time the tank is in use these openings may be closed by means of cast-iron plates made for convenience of manipulation in light sections, and working at the sides in U-shaped guides fixed to the walls, the lowermost being formed so as to fit the semi-circular sludge channel already mentioned.

Scum Boards.—Varying to a great extent with the character of the sewage, at times a small quantity of floating matter will make its appearance on the surface of the fluid. To prevent this passing away with and fouling the effluent, and to retain it until it either sinks to the bottom or can be removed with a skimmer, one or more boards should be placed across the tank partly immersed in the sewage near the inlet end, their depth being such as to keep back the scum without to a serious extent reducing the area of the flow beneath. These scum boards should be made movable, the ends being either secured by metal pins to an iron groove at each wall, or may be hinged at one end and fixed at the other.

Emptying and Cleansing Tanks.—In making provision for the emptying and cleansing of the tanks—which, according to the time of the year, may have to be varied from about every three or four days in summer, to a week, or even more, in winter—the great amount of labour involved where the tanks have to be emptied by hand-pumps should be considered, and every endeavour made to utilise any available motive power for the purpose. Failing this, an attempt should be made to so design the works that the effluent, and if posible, the sludge, may be drawn off separately by gravitation and discharged at some part of the works where the levels admit of it. In the present case, the latter course being practicable, use is made of Alsing's floating valves, one being shown in each tank. These are so designed that the lip of the movable funnel remains supported by a float just beneath the surface, only the top water passing away, until the water level being such that the valve arm rests on the sludge, discharge ceases. Whilst the tank is being worked the arm may be prevented from acting by being suspended by a chain slightly above the water level.

Aerating Weirs.—The importance of subjecting the effluent sewage to the oxidising action of the atmosphere before its application to the land has been very conclusively proved by the valuable experiments carried out by Mr. Sidney Lowcock, A.M.I.C.E., and others, who have shown that a certain amount of oxygen is necessary to the development and existence of those organisms to the presence of which is due the nitrifying action of either natural or artificial filters. One method by which this aeration may be effected is by causing the effluent on leaving the tanks to fall in a cascade motion over a series of steps, the minute quantities of air enclosed being to a great extent retained in the liquid and carried into the pores of the land with the effect of increasing and causing it to retain its purifying properties. This arrangement of weir being practicable in the present case has been adopted, but had sufficient fall not been available a considerable amount of aeration might also have been obtained by a modification of the above, consisting of several long slopes so arranged that the sewage in passing over in a thin film is largely exposed to the atmosphere. A fall of an inch or two at the end of each slope of say 6ft. in width will greatly add to the efficiency of this weir by agitating the liquid.

Construction of Tanks.—As regards the materials to be adopted in the construction of the tanks, much will depend on local circumstance. Ordinarily the bottom may be formed of Portland cement concrete of five parts to one, rendered with finer material and brought to a hard, smooth surface. Concrete faced with blue bricks is, however, perhaps better calculated to withstand the scraping to which it is subjected. The sides may likewise be formed of concrete, but where obtainable hard, well-burnt stocks faced with Staffordshire blues are perhaps preferable. The most perfect lining from a sanitary point of view is undoubtedly that formed of glazed bricks, the only objection to their use being their high cost.

Before passing on to the next portion of the subject, attention may be directed to one or two minor details which, although not appearing of much importance, can but be regarded as errors in design where existing. First, as to the adoption of battered or vertical faces to the inside of tank walls. Experience has shown that the former require more frequent scaling than those carried up vertically; any extra strength required should therefore be obtained by adding to the thickness of the walls from the outside only. Finally may be mentioned the necessity for providing the copings around the tanks and on the cross walls of sufficient width to enable those employed on the works to pass along them in safety; nor should they be weathered any more than absolutely necessary to drain back into the tanks. In one case which came under the author's notice, not only was the weathering excessive, but the entire length of the coping from one end of the tanks to the other was laid in a regular slope, this, besides being a source of continual danger in frosty weather, forming an unnecessary item as regards the cost of construction, owing to the large amount of brick-cutting involved.

Filtration and Irrigation Area.—The clear effluent from the tanks having been thoroughly aerified is now in a condition to be applied to the land, which, according to its nature, extent, and the configuration of its surface, will demand more or less preparation. With a large area in proportion to the population to be dealt with, and provided the surface presents even slopes in definite directions, but little work will be required beyond the laying out of the main and branch carriers in such a manner as to command every portion of the site. When, however, the area at disposal is limited, so that, instead of the sewage of about 100 persons per acre of land, that due to from 500 to 1,000 has to be treated on the same space, recourse must either be had to the use of artificial filters in conjunction with surface irrigation, or the entire area at disposal may, in the manner described hereafter, be brought into such a state as to more nearly resemble a filter in its action upon the sewage.

Intermittent Downward Filtration.—The area of the irrigation site to be utilised not being sufficiently extensive to admit of broad irrigation, it is proposed to adopt the last-mentioned system, in doing which reference may be made to some of its essential features. The main difference between it and other systems, as

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indicated by its name, consists in the intermittent manner in which the effluent is passed on to the land; experiments having shown that, provided a sufficient period of rest is allowed to elapse between each successive application of sewage, the land is not only rendered a more efficient purifier, but is found to retain its properties as such for an indefinite period. In order to show the varying conditions as occurring in practice, one portion of the site is shown laid out on what is known as the bed principle, a method frequently adopted where the land lies level or is subject to temporary inundations. In laying out the land, the site should first be divided up into plots of suitable size and form, any inequalities of the surface being filled up or removed. For the purpose of separating each plot in such a manner as to enable the sewage to be passed on to and retained on any bed as desired, raised banks are usually formed, those constituting the main divisions being properly pitched with stone covered with a layer of gravel or ashes, and of sufficient width to serve as a cartway during agricultural operations. The minor divisions, being narrower, may be utilised as barrow paths to gain access to the distributing chambers.

The remainder of the site, it will be observed, has been treated in a simpler and less expensive manner, the divisions being at greater distances apart, but formed in a similar manner to those already described so as to answer the same purposes. With regard to the distribution, this may be effected by either U-shaped open stoneware carriers or by means of ordinary pipes laid for convenience along the cartways or barrow paths, and provided with outlets at suitable points. In arranging these, the main difference to be observed is that with the bed system irrigation should be possible at several points simultaneously, whilst with a sloping area discharge should take place at certain distances to enable the sewage to be conveyed away by tributary carriers to any part required. The directions of the branch carriers will be determined by the contours of the land, it being only necessary to obtain such a gradient as shall give a velocity of not more than 3in. to 5in. per second in the flow. Nor is it necessary, or even desirable, to employ stoneware or other permanent branch carriers; a channel cut with the spade answering every purpose, besides enabling their position to be varied from time to time as found expedient.

Subsoil Drains.—Perhaps the most essential point upon which the success of intermittent filtration depends is the proper arrangement of subsoil drains. This is due to the fact that in broad irrigation a much larger surface in proportion to the amount of sewage treated being exposed to the atmosphere, much of the nitrification takes place at or near the surface. In the filtration system, however, the subsoil drains, in addition to serving as channels for the collection and conveyance of the effluent, perform the important function of aerating the underlying strata of soil, thus making up for the deficiency of surface exposed to the air. For this reason, the drains require to be placed at closer intervals and sufficient openings provided, particularly at all dead ends, to ensure a thorough circulation of air. Having now dealt with the complete process of purification, it only remains to find a suitable point for the discharge into the river or stream. This being done, any small amount of remaining impurities will be speedily exposed to the oxygenising action of aquatic plants and living organisms, which, placed by the hands of Nature, complete that which human skill has but partially accomplished.

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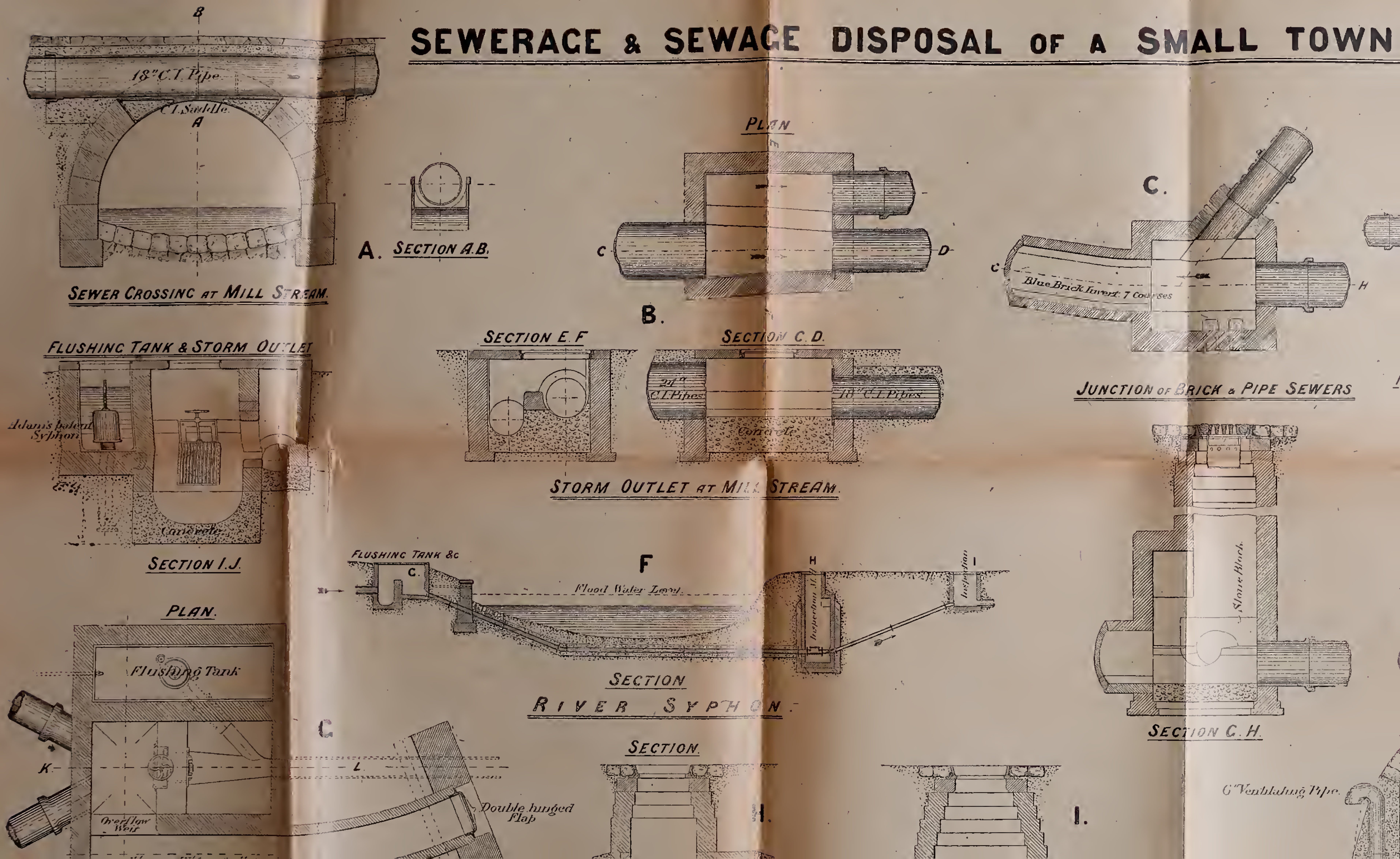

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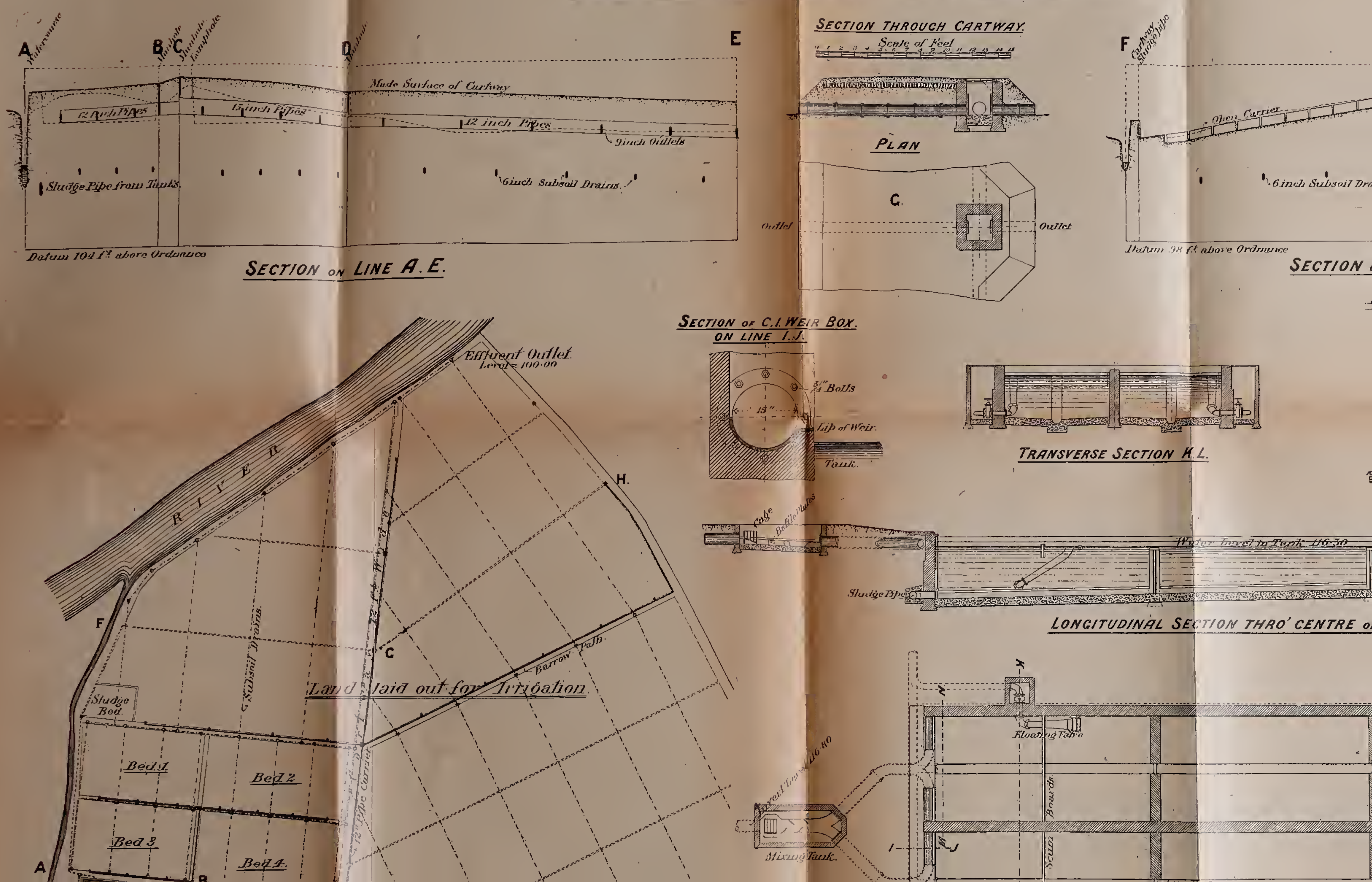

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